INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Fundamentals and Applications of Pressure and External Field Driven Oil-Water Microflows

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SHORT ABSTRACT

Microfluidic devices offer the possibility of scaling down the size of several existing scientific and industrially important equipment having an enhanced efficiency, such as, microreactors- for reaction engineering, microrheometers- for rheological measurements, and microemulsifiers- for emulsification, etc. Due to this reason, it has attracted the attention of many professionals from both industries and academics, and have emerged as a promising area of research. Here, in the present thesis, we aim to explore various aspects of two-phase flow in a microfluidic channel. In order to make a systematic study, the whole work is divided into seven chapters, which are discussed here.

In **Chapter 1**, we present a general overview of two-phase flow in microchannel. A brief literature review on pressure and external field driven two-phase flow in microchannels are described. It also covers a brief literature review on various phenomena and methodologies towards solar energy harvesting. The review of these literatures helped us in identifying various

futuristic alternatives or directions of research which are related to two-phase flows in microchannel. The objectives and layout of the present work have been organised based on the literature review made here.

The design and optimal operation of the contemporary miniature technologies for various applications requires an in depth fundamental understanding of the hydrodynamics of two-phase flows, mainly the flow patterns and its pressure drop studies. In **Chapter 2**, we developed a probabilistic neural network (PNN) model for prediction of flow patterns and their transition boundaries for gas-liquid and liquid-liquid flow systems in microchannels. The percentage accuracy of PNN was found to be higher than the same obtained from various analytical models available in literature. Also, detailed knowledge of the various flow morphologies inside the microscale setups under a varied range of operating parameters have been envisioned to develop various next-generation engineering prototypes. In **Chapter 3**, with the help of experimental and computational study we uncover the effects of pressure driven flow velocity ratio, interfacial tension and viscosity of phases on the flow patterns and pressure drop characteristics of an oil-water flow inside 'T' shaped microchannels. Transitions from slug, to plug, to droplet, to core-annular, to stratified flow patterns were obtained by tuning the oil-water interfacial tension. The study helps in identifying various pathways towards the size reduction of slug length or droplet diameter, which enable the availability of a higher surface-to-volume ratio inside microfluidic devices.

However, the major limitations associated with pressure driven flows are, (a) droplets can be created only for a specific window of parametric space, (b) often the systems require complex geometrical arrangement, (c) requirements of specially modified microchannel surfaces, or (d) addition of surfactants to aid the drop formation. In this direction, an efficient alternative can be the use of external field in breaking down the flow structures into the miniaturized ones having higher surface to volume ratio. In **Chapter 4**, with the help of experiments and simulations we show the deformation, breaking and spraying of droplets into smaller ones due to an applied electric field. The size of ejected droplets was found to decrease with the increase in applied electric field. In **Chapter 5**, through numerical simulations we show that a droplet flowing in a microchannel could undergo breaking multiple times with strategic placement of electrodes along the downstream of microchannel. The proposed methodology shows a simple approach to transform a droplet into an array of miniaturized ones inside a straight microchannel for enhanced mass, energy, and momentum transfer, and higher throughput.

The knowledge and understanding gathered from the fundamental studies of microfluidic technology have always been integrated with other fields of science and technology, for developing miniature devices targeted for a specific application. Some of the applications can be as droplet based reactor, extraction in stratified flow, cell sorting, emulsification, production of nanomaterials, microfluidic based viscometer and tensiometer, and many more. In **Chapter 6**, we have developed a microfluidic based prototype for energy harvesting from light. Here, we show that the generated power density could be enhanced by varying flow rates of the electrolyte and incorporating gold nanoparticles at various concentrations. Finally, in **Chapter 7,** we conclude the thesis with important outcomes from this work and the scopes of future research. A detailed literature review covering various features and applications of two-phase flow in microchannel have been presented below.